CLAIMS

What is claimed is:

1. A test circuit comprising:

   a primary winding which imposes two or more dominant spatial periods of a magnetic field into a test substrate when driven by electric current, the primary winding including two or more coils with different winding distributions, the relative current directions in the coils being switched to provide a different dominant spatial period; and

   at least one sensing element which senses the response of the test substrate to the imposed magnetic field.

2. A test circuit as claimed in Claim 1 where the primary winding comprises discrete concentric loops and the current distribution approximates a first order Bessel function envelope.

3. A test circuit as claimed in Claim 1 where the primary winding lacks a net dipole moment.

4. A test circuit as claimed in Claim 1 where at least one sensing element contains a giant magnetoresistive sensor, the magnetic field being biased in the vicinity of the sensor.

5. A test circuit as claimed in Claim 4 where the magnetic field is biased by an electric current through a coil.

6. A test circuit as claimed in Claim 1 where at least one sensing element contains a SQUID sensor.

7. A test circuit as claimed in Claim 1 where at least one sensing element contains a Hall effect sensor.

8. A test circuit as claimed in Claim 1 where the primary winding contains substantially parallel segments and a linear array of sensing elements containing giant magnetoresistive sensors placed between two adjacent parallel segments.

9. A test circuit as claimed in Claim 8 further comprising a second linear array of sensing elements placed parallel to the first array and offset by half a sensing element dimension parallel to the array direction.

10. A test circuit as claimed in Claim 1 where the primary winding contains substantially parallel segments and a two-dimensional array of sensing elements that spans the footprint of the primary winding.

11. A test circuit as claimed in Claim 10 where at least one sensing element uses a giant magnetoresitive sensor.

12. A test circuit as claimed in Claim 1 where the primary winding contains concentric segments and an array of sensing elements that spans the circumference of one of the primary winding segments.

13. A test circuit as claimed in Claim 12 where at least one sensing element uses a giant magnetoresitive sensor.

14. A test circuit as claimed in Claim 1 where the test substrate contains a magnetizable foam layer having a known thickness.

15. A test circuit comprising:

a primary winding which imposes a magnetic field into a test substrate when driven by electric current, said primary winding designed to have a minimal net dipole moment; and

at least one sensing element which senses the response of the test substrate to the imposed magnetic field.

16. A test circuit as claimed in Claim 15 where the magnetic field distribution of the primary winding is altered so that two different dominant spatial periods for the field are created.

17. A test circuit as claimed in Claim 15 where the primary winding has parallel segments and the surface current distribution in the primary winding follows a sinusoidal waveform, except for the endmost segments where the amplitude of the current decreases to reduce the creation of higher order spatial modes for the magnetic field.

18. A test circuit as claimed in Claim 15 where the primary winding has concentric loops and the surface current distribution in the primary winding follows a Bessel function distribution.

19. A test circuit for measuring material properties comprising:

a primary winding which imposes a magnetic field into a test substrate when driven by electric current; and

a giant magnetoresistive sensor encircled by a feedback coil;

the feedback coil being supplied with a current to bias the sensor and expand the operating range of the sensor.

20. A test circuit as claimed in Claim 19 where an electronic circuit provides the control current to the feedback coil.

21. A test circuit as claimed in Claim 19 where the operating range has a linear response between the sensor output and the magnetic field.

22. A test circuit as claimed in Claim 19 further comprising calibrating the response of the sensor in air, comparing this response to a model, and using the result to determine a material property when the sensor is placed near a test substrate.

23. A test circuit as claimed in Claim 19 further comprising calibrating the response of the sensor near a material having known properties, comparing this response to a model, and using the result to determine a material property when the sensor is placed near a test substrate.

24. An apparatus for measuring volumetric properties in a material comprising:

a primary winding which imposes a magnetic field into a test substrate when driven by an electric current and having a least one linear drive segment; and

an array of sensing elements, at least one of which has a giant magnetoresistive sensor encircled by a feedback coil;

the operating point being maintained for said giant magnetoresistive sensor.

25. An apparatus as claimed in Claim 24 where at least one of the sensing elements is an inductive coil.

26. An apparatus as claimed in Claim 25 where the distance between the drive segment and one or more said linear arrays is varied to sample magnetic fields having different penetration depths.

27. An apparatus as claimed in Claim 24 where the array contains at least one linear array of giant magnetoresistive sensors.

28. An apparatus as claimed in Claim 27 where each giant magnetoresistive sensor is encircled by its own feedback coil.

29. An apparatus as claimed in Claim 27 where a single feedback coil is used for at least two giant magnetoresistive sensors.

30. An apparatus as claimed in Claim 24 where the volumetric properties are the residual and applied stresses in materials having a permeability not equal to 1.0.

31. An apparatus as claimed in Claim 30 further comprising mapping the volumetric properties across the part to create property images.

32. An apparatus as claimed in Claim 24 where the volumetric properties are the magnetic permeability and electrical conductivity and further comprising the use of low frequency excitations to determine the spatial profile of the magnetic permeability and higher frequency excitations to determine the spatial profile of the electrical conductivity.

33. An apparatus as claimed in Claim 32 where the material is a layered media such as a coating on a substrate.

34. An apparatus as claimed in Claim 24 further comprising mounting the drive winding and sensing elements permanently onto a material and where the volumetric properties are the initiation and growth of hidden damage in the material.

35. An apparatus as claimed in Claim 34 where the hidden damage is cracks and corrosion.

36. An apparatus as claimed in Claim 24 further comprising mounting the drive winding and sensing elements onto an accessible side of the material and where the volumetric properties are the temperature on the opposite side of the material and the temperature profile across the material.

37. An apparatus as claimed in Claim 24 where the array contains at least two giant magnetoresistive sensors and further comprising determining the volumetric properies from measurements at several proximities to the test.

38. An apparatus as claimed in Claim 24 where the array contains at least two giant magnetoresistive sensors and one sensor has a different orientation so that a different orientation of the magnetic field is measured.

39. A method for determining properties during a measurement comprising:

locating a primary winding near a test material for imposing a magnetic field into a test substrate when driven by electric current;

measuring the response of a giant magnetoresistive sensor placed within the footprint of the drive winding and encircled by a feedback coil whose current is controlled to maintain the operating point of the sensor;

using a model to generate a database relating the properties to the sensor responses prior to the measurement; and

performing a table look-up operation to convert the sensor response into the properties of interest.

40. A method as claimed in Claim 39 where the properties are the electrical conductivity of the test substrate and the proximity between the sensor and the test substrate.

41. A method as claimed in Claim 39 where the properties are the electrical conductivity and thickness of the test substrate with a known proximity between the sensor and the test substrate.

42. A method as claimed in Claim 39 where the properties are the magnetic permeability of the test substrate and the proximity between the sensor and the test substrate.

43. A method for improving the sensitivity of a magnetic field sensor whereby the relative velocity between the sensor and test substrate is altered in order to vary the depth of penetration of the magnetic field into the test substrate.

44. A method for performing inverse parameter estimation, using least-squares minimization techniques, with the forward estimation step replaced by a forward look-up into precomputed multi-dimensional measurement grids.

45. A method for performing inverse interpolation inside a two-dimensional grid domain continuous in both interpolated parameters comprising:

locating the grid cell that contains the target point by observing the position of the target point relative to a subregion of the grid and dynamically adjusting the subregion until it becomes a single cell;

identifying reference points on the grid cell edges that are associated with the interpolated parameters; and

using a bilinear interpolation to determine the final interpolated parameter values.

46. A test circuit comprising:

a means for imposing two or more dominant spatial periods of a magnetic field into a test substrate when driven by electric current, the means including a means for switching to provide a different dominant spatial period; and

a means for sensing the response of the test substrate to the imposed magnetic field.